# Epidemiology of Beef Tapeworm Infection in the United States

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THE BEEF tapeworm of man, *Taenia saginata*, exists in all areas of the world, from the most primitive to the most highly developed societies. The adult tapeworm is an obligate parasite of the intestine of man, and the larval stage or cysticercus infects the muscles of cattle and, infrequently, other ruminants. Man is infected by eating raw or undercooked beef which contains the cysticerci, so-called measly beef, and cattle acquire the disease by ingesting ova passed by infected human beings. We have not used the term "*Cysticerus bovis*" because it is anachronistic. The "bladderworm" of cattle is not a distinct parasite; rather it is the intermediate stage of *T. saginata*. Therefore, the separate species designation *C. bovis* has no scientific validity.

Because the life cycle of *T. saginata* is so direct, it would seem that in such a highly developed nation as the United States, sanitary measures to interrupt the cycle of infection could be used that would ultimately lead to its eradication. Yet taeniasis in human beings and bovine cysticercosis exist and have existed in the United States for many years. We believe that a clear understanding of the current epidemiologic features of this zoonotic disease is an essential prerequisite to further control measures. We therefore compiled data on the past and present incidence of bovine cysticercosis and taeniasis in human beings in the United States.

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## Bovine Cysticercosis

Data on the annual incidence of cysticercosis were taken from statistics of the Livestock Slaughter Inspection Division, Consumer and Marketing Service, U.S. Department of Agriculture (*1*). These statistics were compiled from the daily reports submitted by veterinary meat inspectors from all federally inspected slaughterhouses throughout the nation. At present approximately 82 percent of the cattle are slaughtered in federally inspected slaughterhouses; the rest are slaughtered in State and municipally inspected abattoirs or are uninspected (*2*). These statistics, however, are a good guide to trends in the incidence of bovine cysticercosis over several years.

Undetected infections for which there are no statistics are more important in perpetuating the disease than the infections that are detected and eliminated. We shall estimate the magnitude of undetected bovine cysticercosis later in the paper.

Federal inspection of all meat and meat products prepared for interstate commerce was established by the Meat Inspection Act of 1906. This

act continues in force; however, the Wholesome Meat Act of 1967 will extend the standards of Federal meat inspection to intrastate commerce within a few years. At the beginning of 1968, meat was inspected by Federal employees in 1,973 establishments in 882 municipalities in the United States.

In 1967, about 28 million cattle underwent ante mortem and post mortem Federal inspection. Of these 14,407 or 0.05 percent had cysticercosis (*1*), an increase of 0.01 percent over the 12,031 cases or 0.04 percent noted in 1966. Comparable data for the past 9 years (table 1) show that the number of infected cattle remained relatively constant, except for 1967 when the percentage of infected cattle decreased because the total number of cattle inspected had gradually increased. Information on annual incidence before 1959 is not available, but some pertinent data appear in the literature. Marx stated that of federally inspected cattle, 0.14 percent were infected with cysticercosis in 1912, 0.37 percent in 1930, and 0.6 percent in 1942 (*3*). Schwartz reported that between 1948 and 1954, 16,500 to 27,000 cattle (estimated prevalence 0.09–0.12 percent) were discovered infected with cysticercosis at slaughter (*4*).

Marked regional differences occur in the distribution of bovine cysticercosis in the United States. Of the 14,407 cases detected in 1967, 72.6 percent were in California, 5.4 percent were in Texas, 2.3 percent were in Colorado, and 2.2 percent were in Arizona. The rate of infection with bovine cysticercosis is now approximately 20 times greater for cattle slaughtered in California than for cattle slaughtered in the rest of the United States.

A number of large commercial feedlots in California have long been plagued with cysticercosis. The economic loss to the feedlot operators is considerable; every animal that is condemned represents a loss of approximately $300, and every carcass that requires refrigeration (at 15° F. for 10 days to kill live cysticerci) represents a loss of approximately $70. In certain areas of California, bovine cysticercosis has been so extensive that feedlot operators buy insurance against losses from this specific disease.

Slaughter of infected cattle is concentrated in the western part of the country, but it would be incorrect to assume that the distribution of potentially infected meat is restricted to this same region. The chain of distribution of cattle and beef in our packing industry is far reaching and complex. For example, investigators of a recent outbreak of bovine cysticercosis in Texas (*5*) observed that 7,568 cattle from the infected feedlot were slaughtered at 20 different abattoirs in eight different States. These plants in turn shipped beef carcasses to widely separated areas in the country—in this particular outbreak, as far east as Rhode Island and as far west as California. Thus, it would appear that persons in all areas of the United States are at risk of acquiring a beef tapeworm infection.

### *Taenia Saginata* in Man

Estimates of the incidence and prevalence of taeniasis in human beings in the United States are more difficult to obtain because there is no

**Table 1. Bovine cysticercosis detected in federally inspected cattle, United States, 1959–67**

| Year | Total cattle slaughtered | Disposition of carcasses with cysticercosis | | | Total infected carcasses | Percent infected |
|---|---|---|---|---|---|---|
| | | Condemned | Retained | Refrigerated | | |
| 1959 | 17, 320, 716 | 108 | 9, 408 | 4, 219 | 13, 735 | 0. 08 |
| 1960 | 18, 454, 319 | 85 | 9, 184 | 4, 031 | 13, 300 | . 07 |
| 1961 | 19, 861, 644 | 91 | 11, 552 | 4, 174 | 15, 817 | . 08 |
| 1962 | 20, 158, 743 | 95 | 10, 223 | 3, 691 | 14, 009 | . 07 |
| 1963 | 20, 859, 520 | 113 | 10, 583 | 3, 941 | 14, 637 | . 07 |
| 1964 | 23, 200, 954 | 118 | 10, 052 | 3, 861 | 14, 031 | . 06 |
| 1965 | 25, 803, 948 | 179 | 9, 419 | 3, 573 | 13, 171 | . 05 |
| 1966 | 27, 373, 829 | 149 | 8, 796 | 3, 086 | 12, 031 | . 04 |
| 1967 | 27, 859, 980 | 92 | 10, 206 | 4, 109 | 14, 407 | . 05 |

SOURCE: Livestock Slaughter Inspection Division, Consumer and Marketing Service, U.S. Department of Agriculture.

**Table 2. Annual *Taenia* identifications made by State health department laboratories, United States, 1963–67**

| Year | Stools examined | *Taenia* identified | *Taenia* identified per 100,000 examinations |
|---|---|---|---|
| 1963 | 380, 599 | 109 | 29 |
| 1964 | 365, 605 | 81 | 22 |
| 1965 | 368, 549 | 80 | 22 |
| 1966 | 377, 963 | 65 | 17 |
| 1967 | 360, 048 | 94 | 26 |
| 5-year total | 1, 852, 764 | 429 | [1] 23 |

[1] Mean stool positivity rate for the United States for the 5-year period.

standard casefinding and reporting system for this condition. Furthermore, infections with *T. saginata* are frequently indolent. Tapeworm infections may be discovered only when the patient happens to note proglottides in his stool (*6*).

We gathered our data by surveying State and municipal health department laboratories to determine the number of stool specimens examined for intestinal parasites and the number found positive for *Taenia* species. This study was abetted by three other sources of information. Fourteen university and metropolitan hospitals and two large prepaid group medical practices submitted similar data. Colleagues who frequently see patients with parasitic diseases were also surveyed. Lastly, the provision to requesting physicians of niclosamide (Yomesan) a new, safe and effective taeniacide, by the Parasitic Disease Drug Service of the National Communicable Disease Center permitted the gathering of more detailed epidemiologic information on newly diagnosed cases of taeniasis (*7*).

In the survey, 43 of 50 State department of health laboratories reported the number of stool specimens examined for parasites and specimens positive for *Taenia* species ova and *T. saginata* proglottides each year for the 5-year period, 1963–67. In addition, the District of Columbia and six large municipal laboratories reported the same data, which are included in the State totals. The seven States not included either did not record *Taenia* identifications or did not reply to our questionnaire. For this 5-year period, the laboratories reported 1,852,764 specimen examinations (table 2). All regions of the United States were represented, and the stool examinations reported represented more than 99 percent of the stool examinations performed by all State health department laboratories.

Ova of *T. saginata* and *Taenia solium* are morphologically identical; however, for the purpose of this survey we have classified all *Taenia* species ova identifications as *T. saginata*. There is a possibility that a few cases of *T. solium* may be included in this total, but we believe that pork tapeworm infections of man seldom occur in the United States. Few infections of cysticercosis have ever been observed in swine slaughtered in this country. Also, of 81 patients with one or more species of tapeworm infection to whom the Parasitic Disease Drug Service supplied niclosamide, only one had a *T. solium* infection (*7*).

During these 5 years, 429 specimens were

**Table 3. Regional *Taenia* identifications from State health department laboratories, United States, 1963–67**

| Geographic area | States reporting | Stools examined | *Taenia* identified | *Taenia* identified per 100,000 stool examinations |
|---|---|---|---|---|
| Northeast | 8 | 122, 109 | 152 | 124 |
| North Central | 10 | 109, 260 | 52 | 47 |
| South | 14 | 1, 531, 980 | 96 | 6 |
| West | 11 | 89, 693 | 129 | 144 |
| United States | 43 | [1] 1, 853, 042 | 429 | [2] 23 |

[1] Includes reports from District of Columbia and six municipal laboratories.

[2] Mean stool positivity rate for the United States for the 5-year period.

positive for either *T. saginata* proglottides or *Taenia* species ova. The mean stool positivity rate for the country was 23 per 100,000 specimens examined. Table 2 shows the *Taenia* identifications for each year and the annual positivity rates. The rates ranged from 29 per 100,000 stools in 1963 to 17 per 100,000 stools in 1966. Interestingly, the decline in *Taenia* identifications in 1963–66 and the subsequent rise in 1967 is parallel to the findings for bovine cysticercosis during the same 5 years.

Five-year rates for the four geographic areas of the country are presented in table 3. These range from 144 per 100,000 stools in the West and 124 per 100,000 stools in the Northeast to six per 100,000 stools in the South. Data from individual States also varied. The 10 States or municipalities with the highest rates (Arizona, California, Connecticut, Hawaii, Maryland, Massachusetts, New York City, Ohio, Rhode Island, and Wisconsin) reported discovering *Taenia* in 277 of the 162,314 specimens examined, for a positivity rate of 171 per 100,000 stools; whereas the 10 States or municipalities with the lowest rates (Alabama, Delaware, District of Columbia, Idaho, Iowa, Kentucky, Nebraska, North Carolina, South Carolina, and West Virginia) reported no positive stools in 320,740 examinations. The health department laboratories reporting the greatest number of cases for the 5-year period were New York City, 103, California, 73, Florida, 45, Hawaii, 37, and Connecticut, 24.

We believe that the 429 *Taenia* identifications reported by health department laboratories represented only a part of the total cases of taeniasis diagnosed in the United States. This belief was supported by the data collected from 14 hospitals and two large prepaid group medical practices (table 4). More than 200 cases of taeniasis were diagnosed in these few institutions during the same 5 years. In addition, several of our colleagues reported seeing more than 20 cases a year in their practices. Interestingly, some of these physicians noted that beef tapeworm infections appeared to be more common in affluent Americans than in the poor. This observation may be explained by the affluent Americans' greater freedom to travel, and also by their more imaginative diets, which may include not only more beef but also rare or raw beef.

The percentage of indigenous cases compared with imported cases was derived from detailed epidemiologic data gathered from patients with recently diagnosed *T. saginata* infections who were treated with niclosamide (Yomesan) provided by the Parasitic Disease Drug Service. It is sometimes difficult to pinpoint the onset of beef tapeworm infections, but for those persons who had not traveled abroad, it was clear that their infection was acquired in the United States.

Of the 57 persons whose travel history was obtained, 19 (33 percent) of the *T. saginata* infections were definitely acquired in the United States, whereas 38 (66 percent) were either definitely or possibly acquired elsewhere. In four persons the epidemiologic evidence suggested that they had acquired the disease from infected meat originating from an epizootic of bovine cysticercosis that occurred during March 1968 in Texas (*5*).

**Table 4. Taeniasis survey of 14 hospitals and two prepaid group practices, United States, 1963–67**

| Geographic area | Institutions | Stools examined | *Taenia* identified | *Taenia* identifications per 100,000 stool examinations |
|---|---|---|---|---|
| Northeast | 2 | 3,418 | 2 | 58 |
| North Central | 4 | 56,596 | 20 | 35 |
| South | 5 | 62,937 | 18 | 29 |
| West | 5 | 63,369 | 171 | 270 |
| Total | 16 | 186,320 | 211 | [1] 113 |

[1] Mean stool positivity rate for the hospitals and medical groups in the United States.

## Case Examples

1. A 33-year-old warrant officer stationed in El Paso, Tex., first noted proglottides in his stool on July 20, 1968. He reported having had vague abdominal discomfort for 2 months. *T. saginata* proglottides were identified, and he was treated with Atabrine.

Despite the fact that he lived in El Paso, the patient had not eaten in Mexico for 10 years. He had had a Scotch-tape examination for pinworms in 1964 and was successfully treated for this condition. No *Taenia* eggs were noted in the specimen at that time. All meat eaten at home was either medium or well done. All his meat was purchased at the base commissary. The commissary was not supplied by any of the slaughterhouses that processed the cattle from the Texas epizootic. Three family members had negative examinations for tapeworm ova.

The only meat he consumed rare was in hamburgers purchased at the snack bar of the post exchange at the military base. The post exchange bought all meat from an El Paso distributor for a large national meatpacker whose slaughterhouse was in New Mexico. The slaughterhouse bought cattle regularly from one of the Texas feedlots involved in the epizootic of cysticercosis and had bought and slaughtered large quantities of cattle from infected herds at the time of the epizootic.

2. A 51-year-old male grocery store owner from Miami, Fla., noted tapeworm proglottides in his stool in August 1968. He was successfully treated with niclosamide. He had no history of foreign travel. He frequently ate rare and raw meat. The family bought all meat directly from a Miami distributor for a large national meatpacker. The Miami distributor's meat came from three major slaughterhouses in Nebraska, Kansas City, and Oklahoma. All three slaughterhouses had slaughtered infected cattle from the Texas feedlots during the epizootic.

3. A 35-year-old white German-born woman noted tapeworm proglottides for the first time in early June 1968. She had been in the United States for 2 years and had not, to her knowledge, been previously infected. All her beef was bought at an Air Force commissary in Omaha known to have received infected cattle from feedlots in Texas involved in the epizootic of cysticercosis. She habitually tasted raw hamburger. In July she was successfully treated with quinacrine and has passed no proglottides since that time.

4. On May 9, 1968, a 40-year-old female X-ray technician from Rhode Island recognized tapeworm proglottides in her stool. For approximately 2 months the patient had experienced mild abdominal cramps, borborygmi, and a change in her bowel habits from relative constipation to bowel movements on arising each morning. She mistakenly believed that she was infected with pinworms and had been looking at her stools each day until May 9 when she first saw the tapeworm segments.

The patient had no history of recent travel. She ate rare beef and often sampled raw meat while preparing hamburgers. She bought all her meat at a supermarket that bought its beef from four distributors. Two of the distributors' sources were slaughterhouses in Nebraska and Iowa that had processed the Texas cattle infected with cysticercosis during the epizootic of March 1968.

Absolute identification of the lot of infected beef that caused each person's tapeworm infection is, of course, impossible. It is clear, nevertheless, that these persons acquired their disease locally and that they all purchased their meat from sources that had processed infected cattle from the outbreak in Texas at a time that was compatible with the onset of their infections.

Despite the fact that the survey of State laboratories encompassed more than 1,800,000 stool specimen examinations for a 5-year period, there were limitations which prevented us from estimating a national prevalence or incidence of taeniasis in human beings. Specimens submitted to these laboratories were not randomly selected, and the *Taenia* identifications were derived in part from routine examinations and in part from examinations of proglottides that were submitted for species identification. Also, the data from hospitals and consultants revealed that a comparatively large number of cases never come to the attention of State laboratories. There are, in addition, many cases that go unrecognized for years. For these reasons, we have not tried to estimate the number of persons infected with beef tapeworm in the United States. Regardless of the exact number of persons infected, our data indicated that there has been significant, continuing transmission of *T. saginata* to cattle and man in the United States.

## Discussion

Stoll in his classic paper "This Wormy World" estimated that there were 100,000 cases of taeniasis in the United States and Canada in 1947 (*8*). A survey by Sunkes and Sellers of health department laboratories in 13 southern

States between 1931 and 1935 showed that six per 100,000 stool samples examined were positive for *T. saginata* (*9*). Their results were identical to ours, three decades later for this region of the United States, but until now there have been no comparable surveys of this scope for other areas of the country. We have shown that 23 per 100,000 stool samples examined by State health department laboratories in the entire United States were positive for *Taenia* species.

Tapeworm infections are probably more common than these data indicate, since many infections are diagnosed in private medical facilities and an unknown number undoubtedly go undiagnosed for many years. Approximately one-third of the tapeworm infections of human beings diagnosed in the United States are acquired in this country. This fact coupled with the knowledge that the annual incidence of detected bovine cysticercosis has remained relatively constant for the past decade indicates that significant transmission is occurring in this country.

What measures can be taken to interrupt the transmission of this zoonotic disease in the United States? One place to attack the disease is in feedlots and on farms. The great majority of infections of human beings in the United States are "dead-end" infections, because the infected persons do not live near cattle. The few that do live near cattle can be potent sources of infection.

It has been estimated that each gravid proglottide contains about 100,000 ova and that the annual output of a single tapeworm is 594 million ova (*6*). In a recent epizootic one tapeworm carrier infected 743 cattle in one feedlot in a 2-month period (*5*). This infection was spread to the cattle through fecal contamination of the silage and cattle pens.

Previous investigations have demonstrated similar modes of spread. Sussman and Prchal (*10*) reported that of 272 Mexican, Indian, and Anglo-Americans and their families on an Arizona ranch where cysticercosis was a problem, four persons (1.5 percent) were observed to have *T. saginata* infections. Two of the infected persons were irrigation foremen who had defecated in and around the irrigation ditches. Greenberg and Dean (*11*) reported a study made by the California State Department of Health in which 8.3 percent of the people on a large cattle ranch had beef tapeworm infections. McIntosh and Miller (*12*) reported that many cases of cysticercosis occurred near Tucson, Ariz., where cattle were grazed on pastures that had been irrigated with sewage effluent. In another instance, near Phoenix, a high incidence of cysticercosis resulted when cattle grazed on vegetable fields that infected workers had previously harvested (*13*).

These studies indicate that cattle can be infected with cysticercosis by pasture contaminated either directly with feces of human beings or with sewage effluent, by feed contaminated by feedlot laborers, and by direct contamination of irrigation ditches and cattle pens by ranch workers.

The degree to which each of these modes of transmission contributes to the annual incidence of bovine cysticercosis in the United States is as yet unknown; however, many outbreaks have been sufficiently well documented to justify the following recommendations for areas where the disease is enzootic in this country: (*a*) institute programs to educate livestock producers and their employees about the life cycle of *T. saginata*, (*b*) pass State sanitary codes that would require examination of stools for *Taenia* of all workers in cattle-feeding establishments before employment, and (*c*) establish State sanitary codes that would require suitable and adequate toilet facilities in cattle-feeding establishments.

Changes in meat inspection procedures can effectively reduce transmission of this disease. Approximately 7 percent of the cattle produced in States where cysticercosis is prevalent are not inspected by Federal, State, or municipal authorities. If the same rate of infection that prevails in federally inspected cattle applies to uninspected cattle, at least 1,000 infected carcasses are consumed each year. Gailiunas (*14*) pointed out that in western Michigan, animals infected with cysticercosis often came from small farms where sanitary conditions were poor and that these cattle were frequently slaughtered in local abattoirs where there was no inspection.

The percentage of cattle inspected by State and municipal authorities varies from State to State. In Texas, for example, 25 percent of the

slaughtered cattle are inspected by the State. No cases of cysticercosis were observed in 1967 in State-inspected cattle in Texas. It is likely, however, that cattle with cysticercosis also pass undetected in intrastate commerce.

Even interstate meat inspection probably does not detect all cattle infected with cysticercosis. The heart and masseter muscles are incised because they are accessible and they have been thought to be the predilection sites for the cysts; however, in a group of 113 lightly infected cattle Viljoen (*15*) noted that 14 percent had no cysts in either the heart or the masseter muscles. In a recent study by Dewhirst and co-workers, in which the inspector was forewarned that infected cattle were about to be processed, 26 percent of the infected cattle passed undetected (*16*). The inspector in this study was not a Federal employee, but he did use standard inspection procedures in favorable working conditions.

Furthermore, a study by van den Heever and Reinecke (*17*) showed that the inclusion of a shoulder incision (not a part of inspection procedures in the United States) increased the detection rate of infected cattle by 47 percent. Thus, routine inspection based on an examination of the heart and masseter muscles probably misses a significant percentage of infected cattle. Jepsen and Roth in Denmark (*18*) and Silverman in England (*19*) asserted that even the most rigorous inspection is inadequate to detect all infections.

More important is the disposition of carcasses known to be infected. Under present regulations if only one dead or degenerated cyst is found in the heart or masseter muscles and further inspection of the diaphragm and tongue does not reveal other cysts, then the cyst is excised and the carcass is passed. Yet, the finding of one dead cyst in the heart or masseters is not sufficient evidence that there is no infection in the rest of the carcass or that, if other cysts do exist, they are equally nonviable.

For example, Viljoen (*15*) demonstrated in 25 minutely dissected animals with heavy infections that the musculature of the front limbs had many more cysticerci than did the heart and masseter muscles. Ginsberg and co-workers (*20*) and Mitchell (*21*) corroborated this finding. Furthermore, Urquhart (*22*), Dewhirst and co-workers (*23*), and Froyd (*24*) have demonstrated that calves and cattle can harbor both viable and dead cysticerci for long periods of time. At present, approximately 70 percent of infected carcasses are trimmed of visible cysts and then passed unrestricted for consumption. (This category is shown as "retained" in table 1.) We believe that all infected carcasses should be either condemned or refrigerated.

Other measures could reduce the propagation of this disease from animal to man; for example: (*a*) institution of active surveillance techniques that would work in conjunction with meat inspection services to perform epidemiologic investigations to pinpoint and eliminate foci of infection and (*b*) development of a sensitive and specific serologic test that would detect animals infected with cysticercosis.

## Summary

A review of the incidence of *Taenia saginata* infection of man and cattle in the United States indicated that the number of cases of bovine cysticercosis detected in federally inspected slaughterhouses had ranged from 12,000 to 16,000 cases a year during 1959–67. In 1967, 72.6 percent of the cases were reported from slaughterhouses in California.

A survey of 43 State health department laboratories for *Taenia* identifications from 1963 through 1967 revealed that of 1,852,764 stool specimens examined, 429, or a rate of 23 per 100,000, were positive for *Taenia* species. Taeniasis was concentrated in the far West and Northeast. Transmission of infection has been occurring within the United States; approximately one-third of the cases diagnosed in the United States were indigenously acquired. To illustrate transmission in this country, four cases of indigenously acquired beef tapeworm infection in human beings probably attributable to a March 1968 epizootic of bovine cysticercosis in Texas were described.

Epidemiologic data indicate that cattle in the United States are infected by feed, water, or pasture, directly or indirectly contaminated by tapeworm carriers. Interruption of transmission can be accomplished by educating livestock producers and their employees, by screening and treating infected personnel on ranches and feedlots, and by improving sanitary facilities in

these establishments. Present methods of meat inspection are good, but they do not detect or properly dispose of all infected carcasses. New techniques for the detection of cysticercosis should be developed, and all infected carcasses should be condemned or refrigerated.

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